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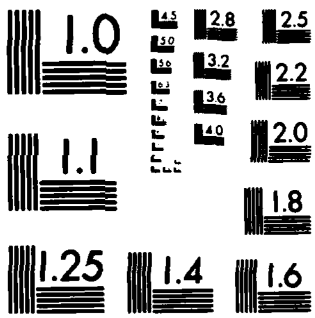

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Films of VN as thin as 5 nm have been made by nitriding V films at high temperature. Tunnel junctions have been successfully made using both oxidized and nitrided amorphous Si barriers. Spin-polarized tunneling results show VN to have a small spin-orbit interaction, but larger than Al. Tunnel junctions have been successfully made on V_3Ga and spin-polarized tunneling shows spin splitting up to 20 Teslas. Structure and compositional analysis of the V_3Ga films has been carried out. We have successfully made high transition temperature Nb films as thin as 5 nm, which is necessary for spin-

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) polarized tunneling measurements to be made. A comprehensive study of amorphous Ge tunnel barriers has been made and compared with theoretical models of tunneling. Many-body effects in Al films have been deduced from measurements of the spin-splitting as a function of magnetic field and temperature in the vicinity of the second order phase boundary.

Summary of Research Goals and Plans

The research goals of this contract are as follows.

- Synthesize materials potentially useful in superconducting electronics.
- Characterize the physical and chemical properties of the materials and their surfaces with analytical instrumentation.
- Form tunnel junctions on thin films of these materials and investigate their characteristics.
- Make transport and tunneling measurements to define the material and junction parameters.
- Explore techniques to enhance the properties of Josephson and single particle tunnel junctions.
- Make spin-polarized and electron-phonon spectroscopy measurements on superconducting thin films.
- Explore promising unusual and advanced materials for superconducting electronics.
- Evolve practical theories to explain the properties of the superconducting materials and the tunnel junctions.
- Compare results with the basic theory of high temperature superconductors to guide research in such materials.

Much progress has been made in attaining these goals. The synthesis and characterization of various materials has been successful and is continuing. Tunnel junctions have been formed on these materials and transport measurements made including spin-polarized tunneling measurements. Materials to enhance properties of tunnel barriers have been studied. Results are being compared with theories to explain the properties of these materials and tunnel junctions. No change in these goals or in plans for attaining them is contemplated.

Status of the Research Effort

The dual electron beam deposition system has been improved with the installation of a liquid-nitrogen cooled baffle. The evaporant passes through a hole in this baffle, which is between the evaporation source and the substrate and serves to trap much of the gas which is evolved from the source during evaporation. This cooled baffle has led to marked improvement in the vacuum conditions during depositions.

VN films have been successfully made by heating V films on a sapphire substrate to about 1300°C in a nitrogen atmosphere. Films as thin as 5 nm have been prepared with transition temperatures close to those of much thicker films. These ultra-thin films were necessary for spin-polarized tunneling measurements. Tunnel junctions were formed on the VN films using amorphous Si oxidized in air. More reliable junctions were formed by treating the amorphous Si with a nitrogen glow discharge giving an effective barrier height of 1.05 ev. Pb counterelectrodes were used. Tunneling measurements showed that $2\Delta/kT_c = 3.7$ for the VN films, showing fairly weak phonon coupling. Spin-polarized tunneling measurements were made at 0.45 K with magnetic fields up to 15 tesla and showed spin splitting above 7 tesla. The tunnel curves showed that the spin-orbit scattering of these VN films is rather small although greater than that of Al. The data will be fitted to theory to obtain a quantitative measurement of the spin-orbit scattering parameter.

Further progress has been made in understanding the many-body effects in Al by comparing the data to recent theoretical calculations of the tunneling conductances. These numerical calculations were developed by D. Rainer and are now an integral part of our data analysis; these calculations are a major advance in interpreting experimental data. The agreement between the theory and experiment for thin films of Al is good. Furthermore the results indicate that the same parameters (spin-orbit scattering, pair-breakers, and many-body enhancements) can be used to fit both the tunneling conductance and the upper critical field. Work is underway to extend the analysis to films of Al with heavy impurities, which will have higher spin-orbit scattering rates.

We have successfully made films of Nb as thin as 100 Å with a transition temperature of 8.5K and 50 Å thick with T_C of 6.0 by using a 10 to 15 Å surface layer of Al to prevent the formation of Nb suboxide. Similar films without the covering film of Al were not superconducting. Such thin films are necessary in order to measure the spin-orbit scattering by a spin-polarized tunneling measurement. As yet no direct measure of this parameter has been made in good quality samples of the transition metal elements Nb, V, Ta. Now measurements of the tunneling spin density of states in Nb appear practical. Combined with critical magnetic field measurements the tunneling measurements can be used to determine the spin-orbit scattering parameter, the penetration depth, the coherence distance and perhaps the many-body corrections, thus determining all of these fundamental parameters.

An extensive series of measurements has been made on the preparation and properties of amorphous Ge tunnel barriers. Amorphous Ge forms junctions with very low effective barrier heights (20-60 mev). This allows junctions of useful impedance to be formed in the thickness range of 5-10 nm. In contrast, tunnel barriers of Al_2O_3 have a height of the order of 1 ev and must be 1.5 - 2.5 nm thick to be of useful impedance. The fact the Ge can be deposited at 77 K to form quite uniform barriers makes it a candidate for applications in both quasiparticle and Josephson tunneling. Elastic tunneling behavior has been demonstrated by observing the exponential dependence of the resistance with barrier thickness in the low temperature region and by observing the energy gap with superconducting counterelectrodes. The voltage dependence of the conductance is also in agreement with the standard tunneling theory. The temperature dependence of the tunneling current has been observed from 300 K to 1.1 K. For temperatures above about 30 K the conduction mechanism obeys the $T^{-1/4}$ law predicted by temperature-activated hopping. Below this temperature the mechanism is mainly elastic tunneling. However, the energy gap structure with superconducting tunneling is broadened and there is conduction at voltages well below the gap which apparently is not the result of elastic tunneling through a simple barrier. The effect of plasma discharges in O_2, N_2, and H_2 on the tunneling properties of a-Ge was studied.

We have used various facilities of the Center for Materials Science at MIT to analyze the thin Nb films and films of various vanadium-based superconductors. The instruments employed include SEM, microprobe, X-ray diffractor, and ESCA. Particularly interesting are the ESCA results on the thin Nb which verify that a thin coating of Al prevents the formation of Nb oxides. Depth profiles of these films using ESCA and argon ion milling imply no oxide formation at the Nb -substrate interface. Exploration of the reasons for depression of T_c in these thin films is continuing.

Publications

What Can We Learn from H_{c2} (T)?, T.P. Orlando, Proceedings of the Tenth Conference on d- and f- Band Metals, edited by W. Buckel and W. Wegner, Karlsruhe, 1982.

Superconducting Properties of VN prepared by Nitriding V Films, P.M. Tedrow and R. Meservey, in preparation.

Spin-Polarized Tunneling Measurement of the Antisymmetric Fermi Liquid Parameter G^o and Renormalization of the Pauli Limiting Field in Al, P.M. Tedrow, J.T. Kucera, D. Rainer, and T.P. Orlando, submitted to Phys. Rev. Lett.

Tunneling Studies in VN Thin Films, P.M. Tedrow and R. Meservey, Advances in Cryogenic Engineering, In press.

Tunneling Measurement of Fermi Liquid Effects in High Field Pauli-Limited Superconductors, J.A.X. Alexander, P.M. Tedrow, T.P. Orlando. Bull. Amer. Phys. Soc. 29, 407 (1984).

Reduction of Thermal Broadening in Superconducting Tunneling Data, G.B. Hertel and T.P. Orlando, Bull. Amer. Phys. Soc. 29, 406 (1984).

Amorphous Ge Tunnel Barriers, G.A. Gibson and R. Meservey, Bull. Amer. Phys. Soc. 29, 406 (1984).

Properties of Ultra-thin Niobium Films, J.H. Quateman and R. Meservey, Bull. Amer. Phys. 29, 554 (1984).

Theory of Fermi Liquid Effects in High Field Tunneling, J.A.X. Alexander, D. Rainer. To be submitted to the Physical Review, March 1984.

Tunneling Properties of Amorphous Ge Barriers, G. Gibson and R. Meservey, To be submitted to Journal of Applied Physics in March, 1984.

A comparison of Theoretical Expressions Commonly Used in Analyzing Tunneling Measurements, G. Gibson and R. Meservey. In preparation, to be submitted to the Journal of Applied Physics.

Spin-Orbit Scattering Rate in VN, P.M. Tedrow, R. Meservey. In preparation to be submitted to the Physical Review.

Spin-Polarized Tunneling Measurement of the Fermi Liquid Parameter in Al, P.M. Tedrow, D. Rainer, and T.P. Orlando, to be submitted in March (1984) to the 17th International Conference on Low Temperature Physics.

Professional personnel

The profesional Personnel associated with the project are:

Prof. T.P. Orlando, Dept. of Electrical Engineering and Computer Science

Dr. R. Meservey, Staff member, National Magnet Laboratory

Dr. P.M. Tedrow, Staff member, National Magnet Laboratory

Dr. J. Quateman, post doctoral associate

J. Alexander, Graduate student, Physics Department

G. Hertel, Graduate student, Physics Department

G. Gibson, Graduate student, Physics Department

Interactions

P.M. Tedrow spent 6 weeks in July and August 1983 at Stanford University working with M. Beasley, R. Hammond, and S. Bending to learn techniques of co-deposition of A-15 compounds.

P.M. Tedrow gave Physics colloquium talk at the University of Connecticut on Spin-polarized Tunneling, October 21, 1983.

T.P. Orlando gave seminar talk at Arthur D. Little on Applications of Superconductivity from a Materials Viewpoint, December 2, 1983.

T.P. Orlando is serving as co-chairman of the program committee for the 1985 International Cryogenic Materials Conference.

J.A.X. Alexander and T.P. Orlando have worked with T.H. Geballe and S. Yoshizumi in measuring critical fields of amorphous Mo-Ge.

R. Meservey has worked with F. Steglich, Technische Hochschule Darmstadt, in attempting tunneling into the heavy fermion superconductor $CeCu_2Si_2$.

G. Bergmann, Julich, visited the National Magnet Laboratory in July 1983 to discuss spin-orbit scattering in superconductors and normal metals.

Low Frequency Losses at High Fields in Multifilamentary Superconductors, A.J. Zaleski, T.P. Orlando, A. Zieba, B.B. Schwartz, and S. Foner, Submitted for publication.

Prof. P. Rainer of Bayreuth University has given theoretical guidance and computer programs for computing the density of states and critical fields of superconductors including many-body effects.

P.M. Tedrow attended the Gordon conference July 4 - July 8, 1983 on the Physics and Chemistry of limited dimensioned systems.